



TITLE:

# <Advanced Research Center for Beam Science>Laser Matter Interaction Science

AUTHOR(S):

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CITATION:

<Advanced Research Center for Beam Science>Laser Matter Interaction Science. ICR Annual Report 2012, 19: 46-47

ISSUE DATE:

2012

URL:

<http://hdl.handle.net/2433/172580>

RIGHT:

# Advanced Research Center for Beam Science – Laser Matter Interaction Science –

<http://laser.kuicr.kyoto-u.ac.jp/e-index.html>



Prof  
SAKABE, Shuji  
(D Eng)



Assoc Prof  
HASHIDA, Masaki  
(D Eng)



Assist Prof  
TOKITA, Shigeki  
(D Eng)



PD  
SHIMIZU, Masahiro  
(D Eng)

## Students

INOUE, Shunsuke (D3)  
MIYASAKA, Yasuhiro (D2)  
NAKAJIMA, Hiroaki (M2)

IKEDA, Daiki (M1)  
KAWAMOTO, Mao (M1)

MAEDA, Kazuya (M1)  
MORI, Kazuaki (M1)

## Visitor

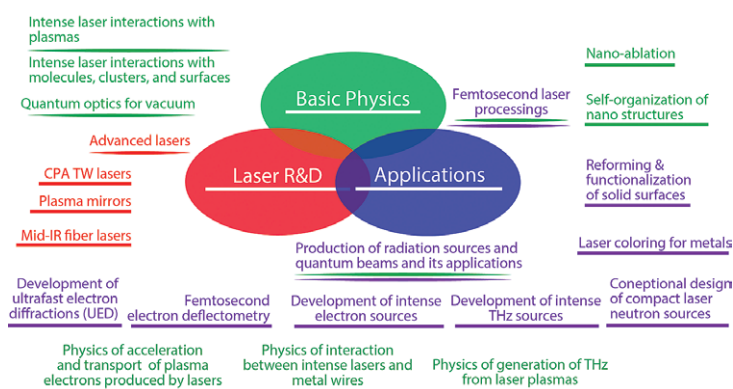
Ms GEMINI, Laura Czech Technical University, Czech R., 15 September–30 November

## Scope of Research

The interaction of femtosecond laser pulses with matters involves interesting physics, which does not appear in that of nanosecond laser pulses. Investigating the interaction physics, potential of intense femtosecond lasers for new applications is being developed (such as laser produced radiations and laser processing). Ultra-intense lasers can produce intense radiations (electrons, ions, THz, and so on), which can be expected as the next-generation radiation sources. Ultra-short lasers are available to process any matters without thermal dissociation. The femtosecond laser processing is also the next-generation laser processing. In our laboratory ultra intense femtosecond laser named T<sup>6</sup>-laser is equipped, and the physics of intense laser matter interactions and its applications are researched.

### KEYWORDS

Intense Laser Science  
Laser Plasma Radiations  
(Electrons, Ions, and THz)  
Ultrafast Electron Diffraction (UED)  
Laser Nano-ablation Physics  
Femtosecond Laser Processing  
Mid-infrared Fiber Lasers



## Selected Publications

Inoue, S.; Tokita, S.; Otani, K.; Hashida, M.; Hata, M.; Sakagami, H.; Taguchi, T.; Sakabe, S., Autocorrelation Measurement of Fast Electron Pulses Emitted through the Interaction of Femtosecond Laser Pulses with a Solid Target, *Phys. Rev. Lett.*, **109**, 185001 (2012).  
Miyasaka, Y.; Hashida, M.; Ikuta, Y.; Otani, K.; Tokita, S.; Sakabe, S., Nonthermal Emission of Energetic Ions from a Metal Surface Irradiated by Extremely Low-Fluence Femtosecond Laser Pulses, *Physical Review B*, **86**, 75431 (2012).  
Jahangiri, F.; Hashida, M.; Tokita, S.; Nagashima, T.; Ohtani, K.; Hangyo, M.; Sakabe, S., Directional Terahertz Emission from Air Plasma Generated by Linearly Polarized Intense Femtosecond Laser Pulses, *Appl. Phys. Express*, **5**, 26201 (2012).  
Inoue, S.; Tokita, S.; Otani, K.; Hashida, M.; Sakabe, S., Femtosecond Electron Deflectometry for Measuring Transient Fields Generated by Laser-accelerated Fast Electrons, *Appl. Phys. Lett.*, **99**, 31501 (2011).  
Tokita, S.; Otani, K.; Nishoji, T.; Inoue, S.; Hashida, M.; Sakabe, S., Collimated Fast Electron Emission from Long Wires Irradiated by Intense Femtosecond Laser Pulses, *Phys. Rev. Lett.*, **106**, 255001 (2011).

## Upgraded Laser System for Higher Quality Pulse Generation

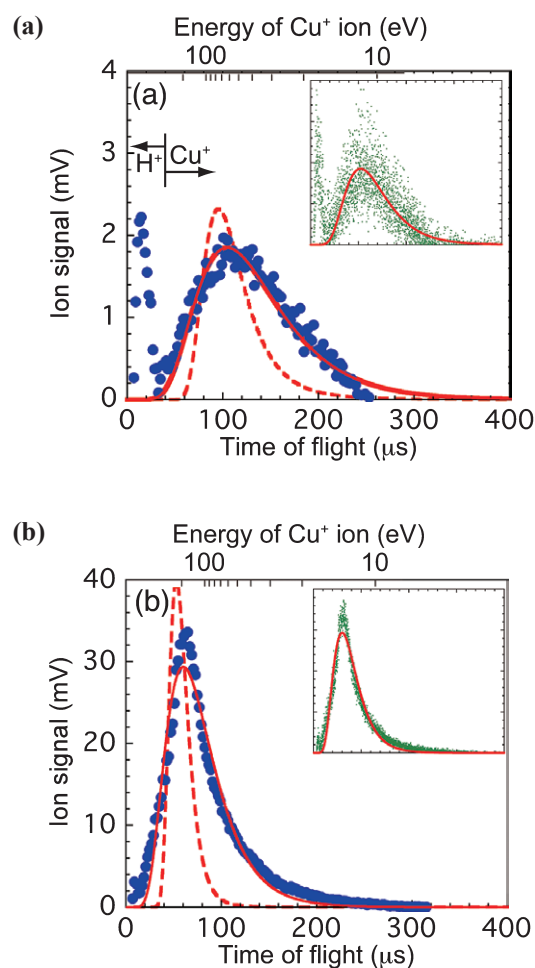
The T<sup>6</sup>-laser has been operated for the study of laser-matter interaction physics and its applications since 1987 (since 2004 at ICR), and lots of fruits were obtained by not only our laboratory members but also the collaboration with another universities and industrial enterprises. For more advanced research, a major upgrade of the laser system was made from April to August 2012. The upgraded points are (1) install of a plasma-mirror pulse cleaner, (2) shortening of pulse duration, (3) accompanying increase of peak power, and (4) install of a programmable femtosecond pulse shaper. Especially for the first point, it is the first development of a high-repetition-rate plasma mirror setup in Japan. The new laser system (Figure 1) delivers 30 fs, 0.5 J pulses (15 TW) with 5 Hz repetition rate. Its frontend incorporates a 10-fs mode-locked laser oscillator, an Offner-triplet-type pulse stretcher, the programmable spectral pulse shaper allowing to optimize the group delay dispersion of the whole system, a 8-pass preamplifier, and a picosecond Pockels cell system for a high contrast ratio of the ASE (amplified spontaneous emission) prepulse to the femtosecond main pulse. The backend of the laser system incorporates the plasma mirror to further improve the contrast ratio, resulting in an estimated contrast ratio of  $10^{-12}$  at 1 ns before the main pulse.



**Figure 1.** A photograph of the new laser system.

## Nonthermal Emission of Energetic Ions from a Metal Surface Irradiated by Extremely Low-fluence Femtosecond Laser Pulses

We have found a new phenomenon of energetic ion emission in extremely low-fluence range. In this research, ions emitted from a copper surface are studied by energy spectroscopy. The energy spectra of ions are investigated considering surface state changes with respect to the number of laser pulses. Singly charged ions with energies of 180 eV are produced at low fluences of  $80 \text{ mJ/cm}^2$ , and the ion energy spectrum does not follow a shifted Maxwell-Boltzmann (SMB) distribution (Figure 2). A new mechanism of ion acceleration, namely, Coulomb explosion of nanoparticles (CENs), is proposed to explain the energy spectra of ions. This mechanism is supported by the relationships of surface-state (self-organized nanostructures) with ion energy and ion emission amounts.



**Figure 2.** The TOF spectra for copper irradiated by femtosecond laser pulse ( $F=80 \text{ mJ/cm}^2$ , 170 fs, 800 nm). (a) Copper surface with mechanically polished and (b) Structured surface structure on copper with femtosecond laser pre-irradiation. Dashed lines and solid lines indicate the calculated SMB distribution and CEN distribution, respectively.